

# Monitoring, Risk Assessment and Management of Exotic Plants in South Korea

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**Abstract**—This study aims to introduce entire system of exotic invasive plants management in South Korea. This system includes risk assessment, monitoring, and management. In risk assessment, qualitative expert assessment has been used but this system will be changed into quantitative or semi-quantitative system soon because of subjective perspectives by reviewers. The monitoring on ecosystem disturbance plant species will be performed by National Ecology Institute level. The management of exotic invasive plants has been conducted mainly by physical method on local and regional level.

**Index Terms**—risk assessment, monitoring, management, exotic plants, south Korea

## I. INTRODUCTION

Invasion by exotic plants has been one of the greatest threats to ecosystem conservation worldwide. And invasive plants inclusive of native species may cause economic impacts. So, prevention and management of exotic plants are urgently needed to reduce economic costs. The term ‘exotic’ indicates not indigenous to Korea, having been introduced intentionally or unintentionally, but having their origins outside of Korea in Korea.

The transport of organisms is an interesting subject to ecologists. The most of dispersals are probably not noticed and dispersal over a species’ range may often occur. Williamson and Fitter [1] have proposed the tens rule, which makes prediction that 1 species in 10 at the end of invasion stage with import, introduction, establishment and being pest become succeed. The previous ranking system of Korea has changed into developed system [2]. My study goal is to investigate into the status and condition of monitoring and risk assessment on exotic plants and their management in South Korea. In Korea, risk assessment of exotic plants depends on qualitative and quantitative assessment method. So, in qualitative assessment method, it is controversial because reviewers are inclined to be based on subjective reasoning. Most of approaches to risk assessment of invasive plant species have been qualitative. Risk assessment schemes are science-based predictions which try to identify species that have not yet been introduced to a region but have a high possibility of becoming invasive [3]. But, Korean risk assessment

schemes include species that have been introduced and do not information for risk.

TABLE I. TOOLS OF RISK ASSESSMENT SCORE FOR EXOTIC PLANTS IN SOUTH KOREA

Items	Contents	Degrees of Risk
Traits of plants	Seed production	nothing, low, medium, high, unknown
	Dispersal ability (wind, water etc.)	nothing, low, medium, high, unknown
	Seed viability(soil seed bank strategy)	nothing, low, medium, high, unknown
Distribution and expansion status	Domestic distribution	unintroduced, established, unidentified
	Distribution status	isolated, locally distributed, widespread
	Expansion velocity	slow, medium, fast
Ecological impacts	Noxious species designation in foreign countries	
	Establishment in domestic ecosystem and damage	nothing, low, medium, high, unknown
	Native species decline and extinction	nothing, low, medium, high, unknown
	Habitat disturbance	nothing, low, medium, high, unknown
	Parasites in native species	
	Host of disease and pest	
	Genetic changes from the crossbreeding with native species	nothing, low, medium, high, unknown
	Impact on protected endangered species	nothing, low, medium, high, unknown
	Ecological influences by noxious materials	nothing, low, medium, high, unknown
	Inhibition on success	nothing, low, medium, high, unknown
Other ecological disturbances	nothing, low, medium, high, unknown	
Class	1,2,3*	decision holding (explain this)
Other suggestions		

\*indicates triple classes of risk (1:high,2:medium,3:low)

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## II. RISK ASSESSMENT

Table I shows the tools of risk assessment score for exotic plants in South Korea. In Korea, risk assessment for exotic plants starts with risk assessment askings. In this stage, local authority and central government authority can ask risk assessment to local environment agency in case that damage occur by exotic organism including plants. Next stage is selection of target species for listings which include species by risk assessment askings in the first stage and species investigated by related institutes. National Ecology Institute is responsible for selection of species for risk assessment. National Ecology Institute should select target species for risk assessment and then specialist groups must determine risk assessment class of target species selected according to risk assessment table (Table I). This risk assessment scheme belongs to qualitative expert assessment. Qualitative expert assessment is usually undertaken by decision specialist panels who use their experience to answer broad questions regarding likelihood of introduction, establishment, impact and management on a qualitative scale (negligible, low, medium and high) and then summarize the overall risk based on these answers [4].

In Korean case, experts determine the risk class of 1, 2, and 3 (Table I). Guidance is sometimes provided in assigning scores and these can be given numeric values so that overall measure of risk can then be calculated by averaging, summing or multiplying [5].

## III. MONITORING OF EXOTIC PLANTS

Exotic organisms of 1109 species invade currently and of these, exotic plants are 309 (Table II). Exotic plants cover about 35% of all organisms but Table I doesn't include fungi, microorganism, moss and fern which don't have treated yet in Korea.

TABLE II. STATUS OF EXOTIC ORGANISMS INVADED IN SOUTH KOREA (HTTP://ECOSYSTEM.NIER.GO.KR/ALIENSPECIES)

Taxon	Appearance	Number
Animal	Mammal	139
	Birds	94
	Reptile	248
	Amphibian	11
	Fish	146
	Invertebrate	162
	Subtotal	800
Plants		309
Total		1109

Exotic invasive plants in Korea according to four periods tend to increase (Fig. 1). Of 309 exotic invasive plant species, Compositae family covers the largest percentage, 20 (Fig. 2). The second and third largest families are Gramineae and Cruciferae.

As a result of risk assessment for exotic plants, exotic plants which can make damage in ecosystem are

designated as ecosystem disturbance species. Thus, current ecosystem disturbance plant species are total 11 (Table III).

The ecosystem disturbance species is similar to the term 'invasive'. The term invasive is defined as introduced from a different area, most often a different continent, which first becomes established, increases in density and expands rapidly across a new habitat [6] whereas ecosystem disturbance species is focused on the point that this species do damage to ecosystem.

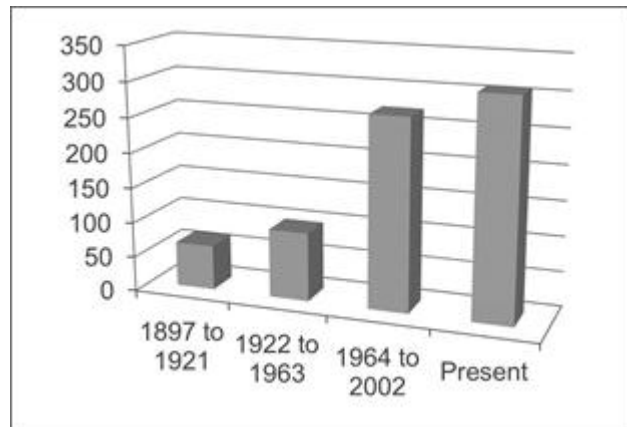


Figure 1. Trend of number of exotic invasives accumulated in South Korea. Year 1897 means port opening in the end of Chosun dynasty.

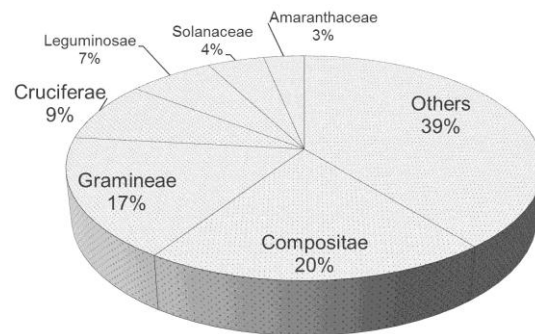


Figure 2. Percentage of 309 exotic invasive plants in Korea by family.

The ecosystem disturbance plant species are target species for monitoring and management. This ecosystem disturbance plant species is formerly named as harmful nonindigenous plants in old exotic invasive plant system of South Korea [7]. The six plant species in old harmful nonindigenous plant system were changed into eleven ecosystem disturbance plant species (Table III). *Eupatorium rugosum* was excluded and *Aster pilosus*, *Hypochoeris radicata*, *Solidago altissima*, *Lactuca scariolia*, *Sicyos angulatus*, and *Rumex acetosella* were added in new ecosystem disturbance plant system.

Another monitoring target species can be potentially invasive plant species which does not yet invade in South Korea. Ministry of Environment, South Korea shall designate and publish potentially noxious plant species which can have a possibility to damage ecosystem if introduced (Table IV, <http://www.law.go.kr/admRulSc.do?menuId=1&query=%EC%9A%B0%EB%A0%A4%EC%A2%85#AJAX>).

All 17 plant species are indicated as potentially noxious plant species in 2014, South Korea (Table IV). The representative landscape elements of Korea were classified into 15 categories: park, airport, riverside(riparian zone), factory district, apartment area, troops outline, roadside, tourist resort, turf field, idle land around housing, waste landfill, forest (forest edge, forest-grassland transition zone, valley, roadside near forest edge), coastal area, constructing lots (housing building area and constructing area) and expressway (resting place and cut-slope). Quadrats were established in all sites and sampling was performed in summer and fall periods (June to October) and Plot size was fixed at 1 m<sup>2</sup> for grassland and 100 m<sup>2</sup> for woody vegetation in accordance with reference [8]. All species were recorded in plots. Taxa names conform to those of reference [9] and reference [10]. All species including trees and shrubs appeared and their cover (%) was recorded to collect flora list total in study sites by random walking along edge line and diagonal axis repeatedly. I stopped searching when we had not found a new species for more than 30 minutes. And I calculated percentage of naturalization per area (PNA) at these study sites (1).

$$\frac{\text{total number of exotic invasive plant species}}{\text{total number of plant species} \times \text{area}} \quad (1)$$

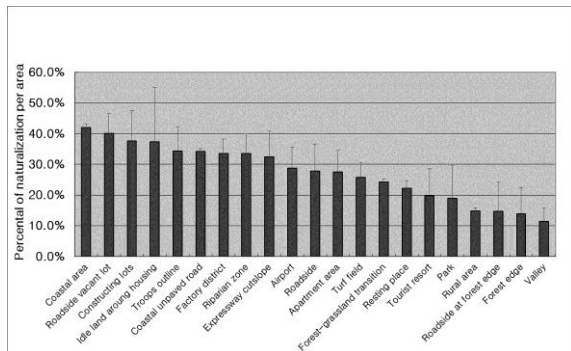


Figure 3. Percentage of naturalization per area (PNA) at diverse landscape patches.

Figure 4. PLANT SPECIES OF ECOSYSTEM DISTURBANCE

Family	Species name
Compositae	<i>Ambrosia artemisiaefolia</i> var. <i>elatiior</i>
	<i>Ambrosia trifida</i>
	<i>Aster pilosus</i>
	<i>Hypochoeris radicata</i>
	<i>Solidago altissima</i>
	<i>Lactuca scariolia</i>
Gramineae	<i>Paspalum distichum</i> var. <i>distichum</i>
	<i>Paspalum distichum</i> var. <i>indutum</i>
Solanaceae	<i>Solanum carolinense</i>
Cucurbitaceae	<i>Sycos angulatus</i>
Polygonaceae	<i>Rumex acetosella</i>

Fig. 3 shows the percentage of naturalization per area at diverse landscape patches as study results. Percentage of naturalization is the ratio of species number of exotic invasives to species number of total plants. The landscape elements with over 30% of naturalization percentage may be taken noticed to manage exotic plants. Of many landscape elements, I want to focus on waste landfill, coastal area and riparian zone with higher percentage of naturalization. Invasion and proliferation of the exotic plants were remarkable at terraces and bank slopes of the riparian zones [11]. Some researchers reported that some exotic plants invaded into national park of well conserved area in South Korea [12].

TABLE III. POTENTIALLY NOXIOUS PLANT SPECIES IN SOUTH KOREA

Species name	Common name
<i>Vinacetoxicum rossicum</i> (Kleopow) Barbar.	Dog-strangling vine
<i>Carduus acanthoides</i> L.	Spiny plumeless thistle
<i>Carduus tenuiflorus</i> Curtis	Slenderflower thistle
<i>Centaurea maculosa</i> Lam.	Spotted knapweed
<i>Chromolaena odorata</i> (L.) King & Rob.	Bitter bush
<i>Mikania micrantha</i> Kunth	Mile-a-minute
<i>Senecio madagascariensis</i> Poir.	Madagascar ragwort
<i>Sphagneticola trilobata</i> (L.) Pruski	Creeping ox-eye
<i>Cenchrus echinatus</i> L.	Southern sandbur
<i>Neyraudia reynaudiana</i> (Kunth) Keng ex Hitchc.	Burmareed
<i>Spartina alterniflora</i> Loisel.	Smooth cordgrass
<i>Spartina anglica</i> C.E. Hubb.	Common cordgrass
<i>Brachiaria mutica</i> (Forssk.) Stapf	Para grass
<i>Vulpia bromoides</i> (L.) Gray	Squirreltail fescue
<i>Fallopia baldschuanica</i> (Regel) Holub	Mile-a-minute-vine
<i>Heracleum sosnowskyi</i> Manden	Sosnowski's hogweed
<i>Hydrocotyle ranunculoides</i> L.f.	Floating marshpennywort

Of exotic invasive plants, there are three tree species in South Korea. The woody species are *Robinia pseudoacacia*, *Amorpha fruticosa* and *Ailanthus altissima*. Recently, *Magnolia obovata* has a trend to increase in urban trees. *Magnolia obovata* is an ornamental tree in South Korea and has been planted in urban landscapes in South Korea. Recent research of *Magnolia obovata* shows that this species can disperse by gravity and animal [13]. Another species of Magnoliaceae, *Magnolia denudata* is in increase in rural landscapes near Cheongju, middle region of South Korea. Also, some exotic creepers are invading into South Korea (Table V).

Of exotic tendrils, *Wisteria floribunda* is a tendril which is distributed on Korea and Japan. This species has been widely used as a horticultural species making shade in garden, school, park and so on in Korea. *Wisteria floribunda* is introduced to Korea at unknown time and naturalized. But, this species aggressively invade into

forests or forest edge because of adaptability to both shade and sunlight, gorgeous sprouting from underground stems, going upward characteristics of the tendril with avoiding improper environment [14].

TABLE IV. EXOTIC TENDRILS IN SOUTH KOREA

Common name	Scientific name	Family name	Life form
Black Blindweed	<i>Polygonum convolvulus</i>	Polygonaceae	Annual
Copse Buckwheat	<i>Polygonum dumetorum</i>	Polygonaceae	Annual
Small Blindweed	<i>Convolvulus arvensis</i>	Convolvulaceae	Perennial
Ivy-leaved Morning-glory	<i>Ipomoea hederacea</i>	Convolvulaceae	Annual
Entireleaf Morning-glory	<i>Ipomoea hederacea</i> var. <i>integrifolia</i>	Convolvulaceae	Annual
Small-flowered White Morning-glory	<i>Ipomoea lacunosa</i>	Convolvulaceae	Annual
Morning-glory	<i>Ipomoea purpurea</i>	Convolvulaceae	Annual
Morning-glory, smallflower	<i>Jacquemontia taminiifolia</i>	Convolvulaceae	Annual
Threelobe Morning-glory	<i>Ipomoea triloba</i>	Convolvulaceae	Annual
Small Red Morning-glory	<i>Quamoclit coccinea</i>	Convolvulaceae	Annual
Field Dodder	<i>Cuscuta pentagona</i>	Convolvulaceae	Annual
Bur-Cucumber	<i>Sicyos angulatus</i>	Cucurbitaceae	Annual
Woolly-pod Vetch	<i>Vicia dasycarpa</i>	Leguminosae	Annual or biennial
Hairy Vetch	<i>Vicia villosa</i>	Leguminosae	Annual or biennial
Crown Vetch	<i>Securigera varia</i>	Leguminosae	Annual
Japanese Wisteria	<i>Wisteria floribunda</i>	Leguminosae	Woody

The domestic study on the vine plants is deficient. Reference [15] investigated into photosynthesis and respiration characteristics at different light intensity and temperature to decipher cultivation use and growth environment adaptable to five *Lonicera* species in western countries including native vines such as *Actinidia arguta*, *Celastrus orbiculatus*, and *Lonicera japonica*. Reference [16] suggested re-vegetation model on 10 species vines useful for plant materials of expressway soundproofing walls. Reference [16] demonstrated that *Paederia scandens*, *Celastrus orbiculatus*, *Lonicera japonica*, *Wisteria japonica*, *Parthenocissus tricuspidata*,

and *Parthenocissus quinquefolia* grow well and could be re-vegetated in 3 years completely. Reference [17] studied the growth environment of vines which dominated at little tree layer because of declined *Pinus thunbergii* forests. The study of reference [17] concluded that vines of tropical origin dominated at light condition produced from degraded tree layer affected by close chemical factories. Reference [18] tested endurance and growth characteristics by changes of soil moisture content for *Wisteria japonica* used for re-vegetation at rocky slopes. Reference [19] showed that seeds of Bur-Cucumber (*Sicyos angulatus*) at first year have higher dormancy and increased growth after June from experiments of changes and early growth. And reference [20] reported that dominance of other plants at Bur-Cucumber community and Bur-Cucumber appears at riparian zone. Reference [21] showed herbicide can be used to control Bur-Cucumber at cultivated and non-cultivated areas.

IV. MANAGEMENT OF EXOTIC PLANTS

Fig. 4 is the mean species number of exotic invasive plants in metropolitan cities and provinces. Seoul, Daegu, and Gwangju metropolitan cities which are colored as yellow in Fig. 4 have the larger species number of exotic invasives than other cities and provinces. So, the management can be conducted in these metropolitan areas earlier and more massively than any other areas. Furthermore, special areas like designated traditional village have been objects to study distribution of exotic plants and some control methods have been suggested although actual methods are not yet done [22]. In Korea, physical, chemical and biological methods to control exotic invasive plants have been applied in field where they dominate. However, chemical methods could not be performed because this may make side effects to pollute and decline other close plants. The biological method has been rarely conducted. The biological method can make secondary effects on the ecosystem in which new organisms to control exotic invasive plants are introduced.

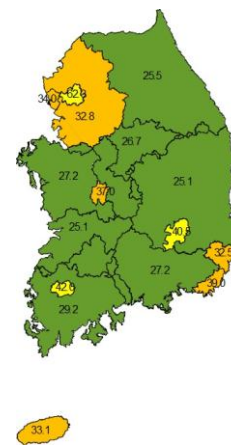


Figure 5. Mean species number of exotic invasive plants in metropolitan cities and provinces.

V. CONCLUSIONS

This study summarizes the status of monitoring, risk assessment and management of exotic plants in South Korea. The monitoring has been executed focused upon species of ecosystem disturbance as target species. The plant species of ecosystem disturbance could be increasing currently. But the criterion whether which species is plant species of ecosystem disturbance or not is not clear because the risk assessment system depends on qualitative scoring system which needs to be more quantitative scientific system now. The management is conducted in regional and local areas, not on governmental scale. A new plan to make monitoring, risk assessment and management more scientific is being established by government lead project.

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